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PREDICTING LOGGING RESIDUES: AN INTERIM EQUATION FOR APPALACHIAN OAK SAWTIMBER

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Abstract.—An equation, using dbh, dbh^2, bole length, and sawlog height to predict the cubic-foot volume of logging residue per tree, was developed from data collected on 36 mixed oaks in southwestern Virginia. The equation produced reliable results for small sawtimber trees, but additional research is needed for other species, sites, and utilization practices.

The increasing interest in utilizing logging residues has created the need for tools and techniques for doing this effectively. It is relatively easy to evaluate residues after logging, but what is more important is to find a method of evaluating potential residue before logging.

If such a method were available, the logging manager would be better equipped to determine what should be done with the residue. If he could estimate the total amount, along with its characteristics such as lengths, diameters, proportion sawable (for mine materials, pallet parts, etc.), and proportion chippable, he would have the basis for deciding what alternatives are feasible. Combining this information with knowledge of equipment and labor costs, market conditions, etc. would permit him to evaluate his options. If residue volumes were too low for profitable removal, he might still be required to treat the slash in some manner; and in this too, prior knowledge would make for better decisions.

To start the search for such a prediction tool, a pilot study was made in 1974 in southwestern Virginia by the Forest Products Marketing Laboratory. The results provided the bases for developing a regression equation

for predicting the volume of residue resulting from the removal of sawlogs.

Methods

Fifty sample trees were selected systematically on a proposed sale area, and the following items were measured before cutting:

- *Species.*
- *Dbh*, taken to 1/10 inch, rounded down.
- *Bole length* (total growing-stock height), between the top of a 1-foot (0.305-m) stump and a 4.0-inch (12.2-cm) diameter outside bark (dob) or to the point where the central stem is terminated by branches, rot, etc., before reaching 4.0 inches (10.2 cm) dob, recorded to the nearest foot. A Wheeler pentaprism was used to locate the minimum top diameter.
- *Sawlog height* (merchantable height), between a 1-foot (0.305-m) stump to the point on the bole above which no sawlog can be produced because of excessive limbs or other defects, or to a minimum top of 9.0 inches (22.9 cm) dob, determined with the pentaprism, recorded to the nearest foot.
- *Crown diameter*, two measurements, taken at a right angle to each other, averaged, and recorded to the nearest foot.
- *Crown class*, either dominant, codominant, intermediate, or suppressed.
- *Defect* (board-foot cull deduction), in accordance with section 102.2 in the *U.S. Forest Service Timber Sale Preparation Handbook.*
- *Tree grade*, in accordance with the procedures in *Interim Hardwood Tree Grades for Factory Lumber*, by Leland F. Hanks (USDA For. Serv. Res. Pap. NE-199, 1971).
- *Branches*, the number of branches that appeared to be larger than 3 or 4 inches (7.6 to 10.2 cm) dob at the small end and 4 feet (1.219 m) or more in length.

The stand was predominately mixed oak (red oak, *Quercus rubra* L.; white oak, *Quercus alba* L.; and chestnut oak, *Quercus prinus* L.) along with some yellow-poplar, *Liriodendron tulipifera* L., red maple, *Acer rubrum* L., and other species. It was an even-aged stand composed of small sawtimber trees. Slopes ranged from 10 to 60 percent. Site index averaged 80 for yellow-poplar and 45 to 50 for oak.[1]

After felling, limbing, and topping, residue measurements were obtainable on 46 of the trees. Large-end and small-end diameters—along with length, defect, and residue class—were recorded for all material $\geq$ 3.0 inches (7.6 cm) dob at the small end. Defect was recorded only if losses for chipping were observed. The residue class indicated whether the piece was bolewood or limbwood, and whether it was straight or crooked. Tree age was determined by counting rings on the stump.

Analysis and Results

Residue measurements were converted by Smalian's formula to volume in cubic feet. Multiple-regression analysis was then applied. Residue volume per tree was the dependent variable, and the standing tree characteristics plus age and dbh^2 were used as independent variables.

The initial tests indicated that yellow-poplar should be omitted, probably because of differences in tree form. The sample contained only a few poplar trees, which by themselves were hardly sufficient for analysis; so the following discussion is based on 36 mixed oaks. Branching habits of the three oak species are very similar; however, they are quite different from that of yellow-poplar.

The variables involved in the analysis are presented in table 1 along with their means, standard deviations, and range within the sample of 36 trees. The simple correlation coefficients for each independent variable versus the dependent variable are also included.

The 12 variables explained 80 percent of the variation in the dependent variable (residue volume per tree). However, after a stepwise deletion process and several subsequent anal-

[1] Hampf, Frederick E. 1965. Site index curves for some forest species in the eastern United States. (Rev.) USDA For. Serv., Upper Darby, Pa. 43 p., illus.

Table 1.—Characteristics of the variables used in the regression analyses

Variable		Mean	Standard deviation	Range within the sample	correlation coefficient Y vs. X_i
Residue volume	(Y)	8.4 ft^3 0.24 m^3	4.6 ft^3 0.13 m^3	1.0-21.0 ft^3 0.03-0.59 m^3	—
Dbh	(X_1)	13.2 in 33.53 cm	1.9 in 4.83 cm	11.1-17.5 in 28.19-44.45 cm	0.598
Dbh^2	(X_2)	178.4 in^2 1150.97 cm^2	51.9 in^2 334.84 cm^2	—	.578
Bole length	(X_3)	48.4 ft 14.8 m	10.9 ft 3.3 m	27.0-72.0 ft 8.2-21.9 m	—.022
Sawlog height	(X_4)	32.2 ft 9.8 m	9.8 ft 3.0 m	15.0-59.0 ft 4.6-18.0 m	—.267
Crown diameter	(X_5)	27.3 ft 8.3 m	5.5 ft 1.7 m	17.0-38.0 ft 5.2-11.6 m	.470
Crown class*	(X_6, X_7)	—	—	—	—
Defect	(X_8)	8%	9%	0 - 30%	.162
Tree grade*	(X_9, X_{10})	—	—	—	—
Branches	(X_{11})	2.6	1.5	0 - 6	.596
Age	(X_{12})	57 yr	11 yr	27 - 75 yr	.199

* Dummy variables were used for the three crown classes and the three tree grades that were encountered in the sample.

yses, it was found that an equation containing four variables (X_1 through X_4) explained 73 percent of the variation in Y ($R^2 = .729$, $S_{y.x} = 2.57$):

$$V = -88.209 + 13.224D - 0.415D^2 + 0.177BL - 0.400SH$$

where:

V = Residue volume/tree of all material $\geq$ 3.0 inches dob, in cubic feet.

D = Dbh, in inches.

BL = Bole length(as previously defined), in feet.

SH = Sawlog height (as previously defined), in feet.

If dbh is measured in centimeters, and bole length and sawlog height are measured in meters, residue volume in cubic meters per tree can be estimated with the equation ($S_{y.x} = 0.073$)

$$V = -2.402 + 0.142D - 0.002D^2 + 0.017BL - 0.037SH$$

Although the four-variable equation differs little in statistical quality from that obtained with the full set of variables, it relates much better to the field data collected in a typical timber cruise. And, of course, measurement time has a direct bearing on costs.

It should be mentioned that even though bole length is poorly correlated with residue volume, and is highly correlated with sawlog height, it is still an essential part of the equation. This is understandable, however, because residue volume is partly a function of the difference between bole length and sawlog height.

Discussion

Because the equation is the product of a preliminary study with limited data, its use should be restricted to the smaller trees in mixed oak stands.

Because of this limitation, we are going to continue the study on a much larger scale. Sampling will be stratified so that differences (if any) between species, sites, cutting practices, merchantability standards, etc. can be detected. If the differences are significant, separate equations and/or tables will be prepared.

Obviously, residue resulting from small merchantable sawlog trees represents only part of the material that remains after logging. However, this study represents a step toward developing more complete knowledge about residue.

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